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JANUS: A TECHNIQUE FOR IDENTIFYING OPERATIONAL ERROR CAUSAL FACTORS

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Although human error has been repeatedly identified as a dominant risk factor in safety-oriented industries such as air traffic control (ATC), little is known about the causal factors leading to human and ATC operational errors. The Federal Aviation Administration developed and tested the JANUS technique to better understand the role of human performance in operational errors. The results yield converging evidence that the JANUS technique appears to be more sensitive, useful, comprehensive, and practical than the current processes to identify causal factors. The results also suggest that the technique has great potential for application, although some work still needs to be done to support operational implementation.

Background

The US Federal Aviation Administration (FAA) oversees the largest, safest, and most complex aviation system in the world, relying on a workforce of highly trained air traffic control specialists who interact with an environment of radar, computers, and communication facilities to maintain the safety and efficiency of the system. In fiscal year (FY) 2000 alone the US air traffic system handled 166,669,557 operations. Operational errors (OEs) have long been an important metric for understanding safety trends in the National Airspace System (NAS).

An operational error is defined as an occurrence attributable to an element of the air traffic system in which (1) less than the applicable separation minima results between two or more aircraft, or between an aircraft and terrain or obstacles (e.g., operations below minimum vectoring altitude (MVA); equipment / personnel on runways), as required by FAA Order 7110.65 or other national directive; or (2) an aircraft lands or departs on a runway closed to aircraft operations after receiving air traffic authorization, or (3) an aircraft lands or departs on a runway closed to aircraft operations, at an uncontrolled airport and it was determined that a NOTAM regarding the runway closure was not issued to the pilot as required (FAA Order 7210.56, 2002).

The reduction of ATC operational errors has been a part of the FAA's safety initiatives for a number of years. Calculated as a percent of facility activities, the operational error (OE) rate per 100,000 activities increased from .60 in calendar year (CY) 1999 to .69 in CY00 and .74 in CY01, then declined by 11% to .66 in CY02[1] (FAA, 2003a). .Although air traffic declined after the events of September 11, 2001, the OE rate reflects the continuing need to identify mitigation strategies. To accomplish this, the FAA has a formal quality assurance reporting process to record event descriptions and causal factors.

Because the air traffic system relies on a workforce of highly trained air traffic control specialists (ATCSs), the FAA has increasingly focused on human performance as an important part of a comprehensive quality assurance program. Although often not the only factor, human performance is frequently the mechanism which translates factors of the situation into an OE. For example, several studies of runway incursions[2] classified as OEs identified several types of human error associated with runway incursions , such as the controller's issuance of a conflicting clearance, as memory errors (e.g., forgetting about aircraft or about previous coordination with other controllers), coordination errors (e.g., incomplete or misunderstood coordination between controllers or between pilots and controllers), missing supervisory redundancy to 'back up' the controller, controllers' observation of aircraft, failure to scan, failure to prioritize (Bellatoni & Kodis,1981; Cardosi & Yost, 2001; Kelley, Krantz, & Spelman, 2001; NTSB/SIR-86/01; Schroeder, 1982; Weitzmann, 2001). These studies are remarkable for their redundancy. They identify much the same issues as candidates for intervention strategies: controller's skills, procedures, and equipment. Most also recommend a better method for investigation of operational errors so that better (more informative) data can be collected for analysis.

Although human error has been repeatedly identified as a dominant risk factor in safety-oriented industries such as air traffic control (ATC), little is known about the causal factors leading to human errors in current systems. The first step toward prevention is to develop an understanding of where human error occurs and why it occurs. Thus, understanding human behaviors, human errors, and their relationship with OEs is important to understanding how to manage their impact on the system. In concert with

[1] Calculations of rates use fifteen decimal places but are rounded to two places for the table on page 6 of the FAA Administrator's Fact Book.

[2] A runway incursion is any occurrence at an airport involving an aircraft, vehicle, person, or object on the ground that creates a collision hazard or results in a loss of separation with an aircraft. The occurrence may involve a pilot taking off, intending to take off, landing, or intending to land (FAA Order 7210.56, 2002; pg 4-1).

Eurocontrol, the FAA undertook to develop a method to better understand the role of human performance in OEs. Conclusions from this work were used to develop and test a structured interview technique identify factors influencing ATC performance expressly suited to the unique FAA ATC environment.

The FAA's Flight Plan for fiscal years 2004 to 2008 includes several initiatives to reduce OEs: study of airspace complexity, implementation of ATC performance enhancement training, and using JANUS to help understand the causes of operational errors (FAA, 2003b). JANUS is a structured interview method for retrospective analysis that helps the analyst identify the mental processes and contextual conditions leading to the OE. The method examines the event as a time series of critical points. The technique was developed based on two pre-existing taxonomies and aims to aid the analyst in retrospective analysis of operational errors to better understand the points at which human and system errors lead to adverse outcomes in the ATM environment. The outputs identify a controller's mental processes and contextual factors by viewing the individual as part of the larger human-computer-organizational system. Development of the technique was detailed in Pounds and Isaac (2002).

Method and Results

A beta test of the technique was conducted at volunteer ATC facilities from December, 2001 to August, 2002.[3] Of those 29 facilities volunteering, data from 79 OEs were collected at 13 sites in 215 interviews. These data and feedback from the participants were used to validate the process. For example, Table 1 shows the major headings of the technique and results of data from the interviews with the 79 controllers who were working the traffic at the time the OE occurred. The numbers depict the frequency that the causal factor category was identified as an influence during the event over the 315 critical points analyzed. Table 3 shows data from all interviews related to the event's contextual conditions.

The results demonstrated that the JANUS technique should capture more causal factors compared to the existing OE reporting process, that the JANUS technique will provide added value beyond the existing OE reporting process, will help identify causal factors and contextual conditions of OEs. Agreement between users was modest and work is ongoing to identify ways to increase the agreement between users.

Participants' feedback and an ATC expert forum suggest that the time required to use the JANUS method was reasonable, although the amount of effort to analyze and process the incident data is still to be determined so that appropriate feedback can be developed. Participants were comfortable with the interview procedures, the software application, and use of the obtained data. Future work is needed to develop a larger dataset of OE factors so that trend analysis can be conducted. These can then be used to connect the data to strategies and to derive system improvement techniques that can be implemented.

Table 1. Categories of mental processes and contextual factors identified.

Mental Processes	
• Perception & Vigilance	41%
• Memory	15%
• Planning & Decision Making	49%
• Response Execution	10%
Contextual Factors.	
• Traffic & Airspace	49%
• Weather	28%
• Teamwork	26%
• Pilot Actions	21%
• Personal Factors	21%
• Pilot-Controller Communications	20%
• Ambient Environment	18%
• Equipment & HMI	13%
• Procedures & Orders	11%
• Training & Experience	10%
• Supervision & Mgmt	10%
• Organizational Factors	10%
• Interpersonal & Social	5%
• Documents & Materials	0.3%

The results yield converging evidence that the JANUS technique appears to be more sensitive, useful, comprehensive, and practical than the current processes to identify causal factors. Both objective data and subjective data support the approach. These results also suggest that the technique has great potential for application, although some scientific work still needs to be done to support operational implementation.

By increasing understanding of how human performance results in human error, strategies for supporting ATC expert performance can be developed and inhibiting performance shaping factors can be reduced, all contributing to increased safety in the national aviation system. For example, a program to address factors related to perception and vigilance has been developed and field tested at several air traffic control facilities. To support initiatives in the FAA Flight Plan, future programs will be developed

[3] Details of the beta test and validation are discussed in more detail in Pounds and Isaac (2003).

based on the trend data gathered by the JANUS technique.

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